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STUDY ON METHOD FOR EVALUATION BUS RAPID TRANSIT (BRT) SCHEME

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Abstract: To implement bus rapid transit (BRT) on urban road is one of the effective means of urban traffic management that is helpful to improve urban transportation condition, and to raise the public transit service level. In order to judge the effect of BRT projects after enforcement, it is necessary to evaluate BRT scheme quantitatively. The BRT scheme evaluation is multi-subject and multi-objective. This paper established a set of evaluation indexes including social economy factors, traffic function factors, environment effect factors and resources utilizing factors by taking managers, users and relatives as the subject of scheme evaluation. Some relative indexes are filtered by the fuzzy clustering analysis method of independent minimum variables. At last, a more objective and operative method, multi-layer fuzzy comprehensive evaluation method, is chosen to evaluate the BRT schemes, and an application example is shown to prove the efficiency of this method.

Key Words: bus rapid transit (BRT), transportation planning, urban public traffic priority, evaluation index

1. INTRODUCTION

Implementing bus rapid transit (BRT) priority measures on urban road is an urban transportation management method. While urban transportation system is an extremely complex system, in which any changes of transportation management measures will cause a variable traffic flow on the whole transportation network, called “Pull one hair and the whole body is affected-a slight move in one part may affect the overall situation”, and this kind of change can’t be judged accurately by experience. Therefore, in order to evaluate the effect of BRT schemes in an overall way, it is necessary to study the whole transportation network. Evaluation indexes should include many aspects such as technology, economy, society, environment, etc. By quantitative evaluation of BRT schemes, the effect of BRT can be known before implemented, which can prevent making a wrong strategic decision and play a determinate role in choosing the ultimate BRT scheme.

2. BRT SCHEME EVALUTION PROCESS

Scheme evaluation process includes two stages in a full sense: First stage is to forecast the influence that the scheme may be generate. It is to forecast the traffic flow and the level it has reached since each scheme implemented. Its nucleus technique is traffic assignment, then to analyze the traffic passing quality judge whether it is a feasible scheme. That if the scheme is unfeasible it needs adjust, analogue and do quality analysis more till it is feasible. The major job of this part is: ① to analyze BRT project how to affect the urban traffic mode structure and stream in the traffic network; ② to forecast the operational indexes of the urban traffic system stream when the BRT project is implemented; ③ to analyze whether the BRT scheme reaches the preset aim. This step is called the scheme's "effect forecast" of which can get a feasible scheme (or a alternative one) and acquires the scheme's evaluation index value.

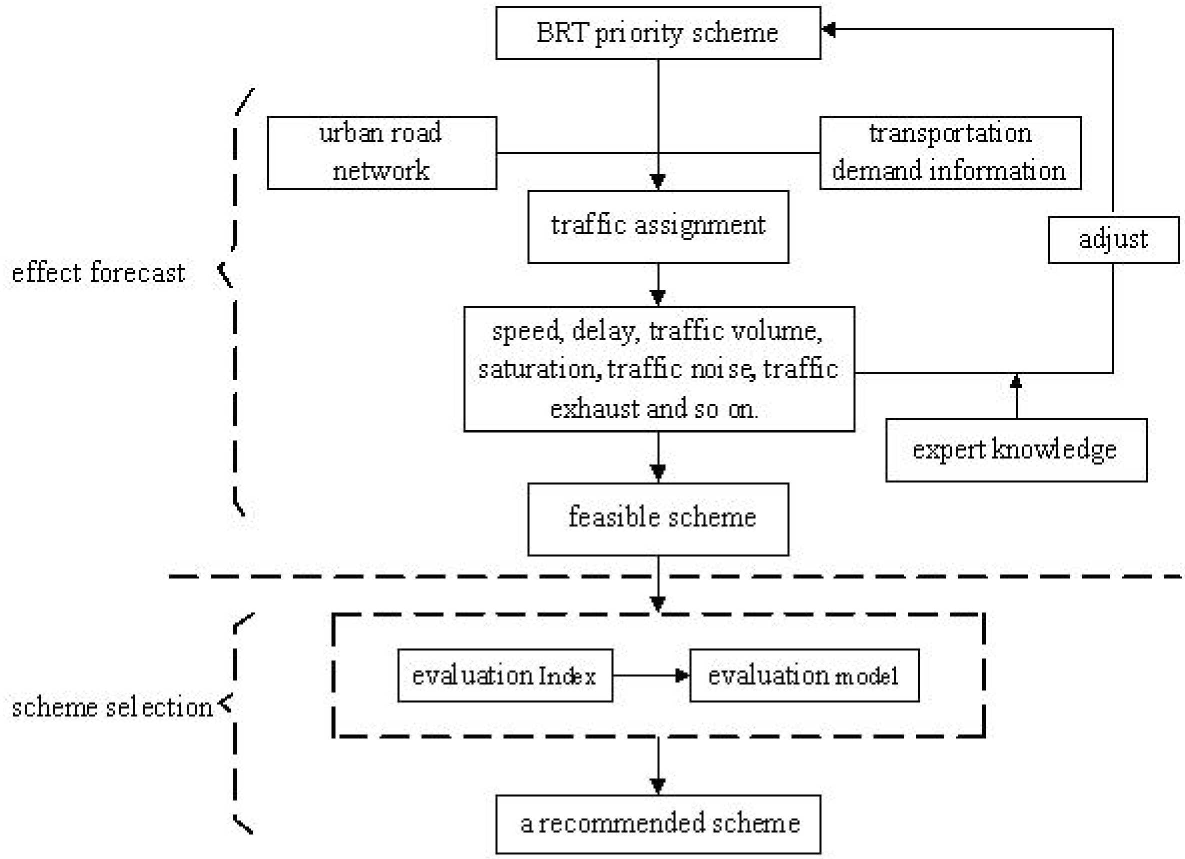

Figure 1. BRT Scheme Evaluation Process

The second stage is the feasible scheme's sequencing and optimum selection, which is to draw a reasonable evaluation index system according to a series data on the base of above all, and then to adopt a given evaluation model to compare and choose alternative schemes and pick out the best one or some good ones as recommended schemes. This step is called "scheme selection". That study on scheme selection has two tasks: first, to found a scientific and reasonable evaluation index system; second, to determine evaluation method adopted which is also called evaluation model.

An integrated BRT scheme evaluation is united by effect forecast and scheme selection. BRT Scheme Evaluation Process is shown in figure 1. Effect forecast is the base of scheme selection and scheme selection is the ultimate purpose of effect forecast.

3. STUDY ON BRT SCHEME EVALUATION INDEX SYSTEM

3.1 Evaluation Objective

BRT Scheme project is a multi-subject and multi-objective evaluation. In the past great vast majority transportation planning put particular emphasis on signal evaluation subject. It can catch the main contradiction but not comprehensive. In this article, the following three subjects are regard as BRT scheme evaluation subjects for the purpose of improving its inadequate. They reflect the scheme influence basically:

- construction managers, being defined as urban construction department, transportation management department, municipal engineering department or other government departments;
- users, being defined as motorized vehicles, non- motorized vehicles, pedestrians and other traffic participators;
- the relevant ones, being defined as residents around who are subject to traffic influence.

With regard to evaluation objective, for construction managers, they hope that BRT can not only promote forming reasonable traffic structure and create fine city image but also demand a little facilities construction invest; for users, evaluation items include speediness, convenience, comfort, security, cheapness, etc; for the relevant ones, they pay close attention to the environment influence and fuel consumption that traffic generates. The overall evaluation objective is to compare several BRT scheme and choose a best ultimately. The optimum scheme is one that can get better traffic quality with less social economical input, less environment influence and resources consumption.

3.2 Determining Evaluation Index

Since BRT scheme gives bus priority, which means that the road resources will not be allocated at average level to all vehicles, in limited road it gives public traffic more road resources and the social vehicle (non bus) road resources will be reduced. It maybe bring short period effect that includes raising bus network service level (such as speed raising and rate of punctuality), social vehicles speed falling, saturation raising in districts where permit social vehicles passing, social vehicles delay increasing, environment deteriorating possibly in short period (such as air pollution and noise pollution increasing), and average travel expenses raising. While its long period influence may be: city residents travel mode's structure proportion changed as a result of social vehicles' passing quality falling and public traffic service level raising, such as social vehicles travel, non-motorized vehicles travel, etc will transfer to public traffic. Above all, the effect that BRT scheme brings when it is implemented includes:

- Influence to social economy. To implement BRT scheme needs human resources, material resources and financial resources, in other word, it needs economic resources input and there are diversity between different schemes. But the bus service level raised will change the urban residents' travel mode structure proportion, so the travel cost will also change as it.
- Influence to traffic function. To implement BRT scheme will cause a series of

change such as public traffic and social vehicles' speed, delay, segment or intersection saturation, traffic travel mode structure.

- Influence to environment. There are diversity between the traffic environment pollution degrees caused by different travel mode, so to implement BRT scheme can change travel mode , and then cause traffic environment pollution changed [1].
- Influence to resources utilization. There are diversity between the traffic energy utilization efficiency caused by different travel mode, so to implement BRT scheme can change travel mode , and then cause traffic energy utilization efficiency changed.

The principle to select evaluation indexes is one that can reflect the most principal and overall information with least indexes. In this article the principle to definite evaluation will combine requirement and possibility with full consideration: first, it can reflect the principal evaluation subjects and its objective; second, the indexes value can be acquired easily and quantitative best. This article proposes some alternative indexes for BRT scheme.

Table 1. Having Been Selected Evaluation Index Set for BRT Scheme

Index type	index code	index name
social economic indexes	U_{11}	BRT facilities construction invest
	U_{26}	average resident travel cost
traffic function indexes	U_{21}	average social vehicle speed in arterial road
	U_{22}	average public traffic speed in arterial road
	U_{23}	average saturation degree in arterial road intersection
	U_{24}	average social vehicle delay in arterial road intersection
	U_{25}	average public traffic delay in arterial road intersection
	U_{12}	public traffic travel proportion
influence to environment indexes	U_{31}	intersection air quality exceeding rate
	U_{32}	segment air quality exceeding rate
	U_{33}	road traffic's air pollution saturation degree
	U_{34}	average traffic noise value in arterial road
	U_{35}	average traffic noise value in intersection
resources utilization indexes	U_{36}	fuel exhausting per passenger transportation volume
	U_{37}	traffic space resources exhausting index

When the alternative indexes are established, the correlation degree of different indexes must be analyzed and get rid of the high correlation degree indexes. This step can adopt factor analysis method, clustering analysis method, etc in mathematical statistics, but these method demand enormous and systematic data which is relative difficult to gather in China now. Document [2] provides a minimum independent variable fuzzy clustering analysis correlation method for evaluation indexes. This method makes up of all evaluation indexes as a evaluation set in which set a signal index's all minimum independent variables are made up as a factor set, and then do fuzzy clustering analysis according to the degree that the evaluation set's elements set memberships to the factor set's. It adopts minimum independent fussy clustering analysis to select alternative evaluation indexes for BRT scheme, while considers if the index value can be acquired easily. Each independent evaluation index this article proposes adopt for BRT scheme is shown in Table 1.

3.3 Evaluation Index System Structure

The evaluation index system structure is divided into three types: unary structure, linear structure and tower structure [3]. This article takes a method according to principle and aim to figure tree-layer to definite index system structure. It takes "selecting satisfy scheme" as the top layer, the principle evaluation objective as the second layer, the evaluation index to each principle objective as the third layer and the scheme layer as the bottom layer, which is shown in Figure 2.

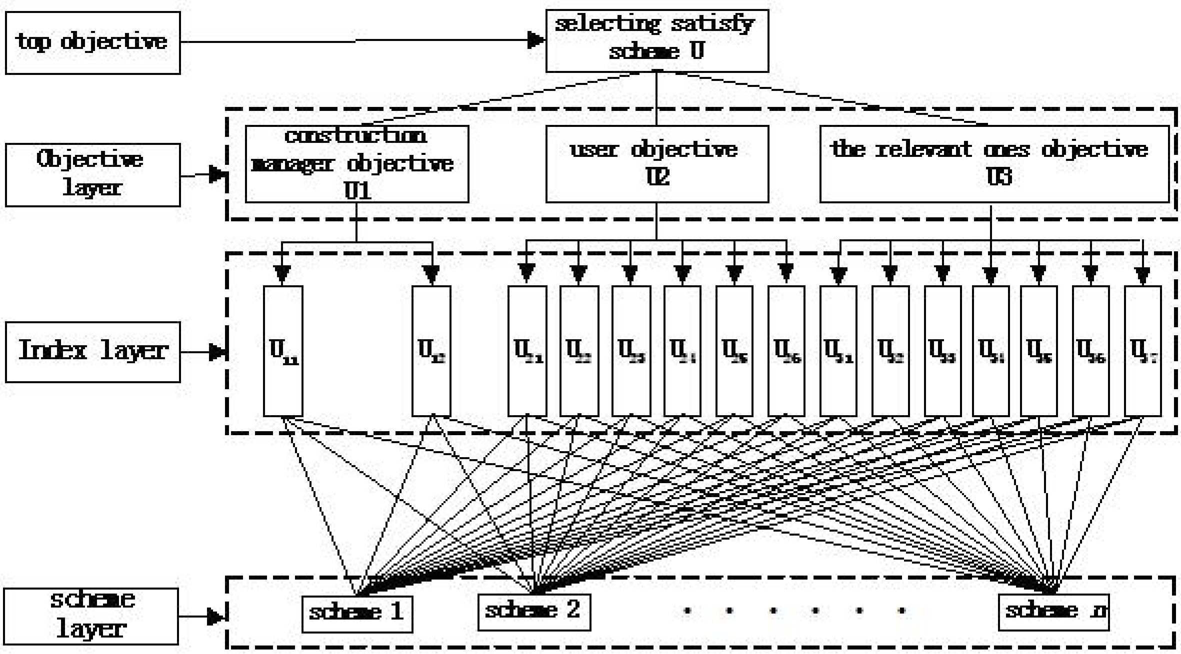

Figure 2. Evaluation Index System Structure of BRT Scheme

3.4 The Acquiring Method of Evaluation Index Value

We may get the all evaluation index quantitatively with the help of "TranStar (Traffic Management Version)"[4], which is a software supporting traffic management. Especially, this software developed an environment influence evaluation mode which can evaluate fuel exhausting, noise environment and atmosphere environment. This is also the main reason why it chooses these indexes. That's to say we must consider the method of study in choosing indexes carefully.

4. EVALUATION METHOD AND APPLICATION ANALYSIS

4.1 Multi-layer Fuzzy Comprehensive Evaluation Method

There are value function method, analytic hierarchy process (AHP) method, fuzzy comprehensive evaluation method, data envelopment analysis (DEA) method, neural network method, etc for multi-index comprehensive evaluation method of complicated object in home and abroad. The study of this field has been mature. It is obvious that in evaluating the BRT scheme we must think of different aspects, different layer indexes. So this is a typical multi-layer comprehensive evaluation problem. And others, although each index in the evaluation index system which is advised in this article can acquire in quantity. The evaluation standard of these indexes is difficult to be given definitely. At least it can't give only one value. So this is a typical fuzzy system. Based on the above analysis, this article adopts multi-layer fuzzy comprehensive evaluation method that combines AHP and fuzzy comprehensive evaluation method [5].

AHP is a system evaluation method, which combines quantum and nature, and is also a good method to dealing the weight of complicated problem. The key step of AHP is to construct uniformly judgment metric. But in factual problem, it is difficult to construct a suitable judgment metric just trying one time. It can be corrected by adopting the correction method in document [6] when an initial judgment metric don't satisfied uniformly. This method's calculation process is shown in Figure 3, where $A(a_{ij})$ expresses initial judgment matrix, $A^*(a_{ij}^*)$ expresses judgment matrix corrected that satisfies uniformly. $A(a_{ij})$、$A^*(a_{ij}^*) \in R^{n\times n}$.

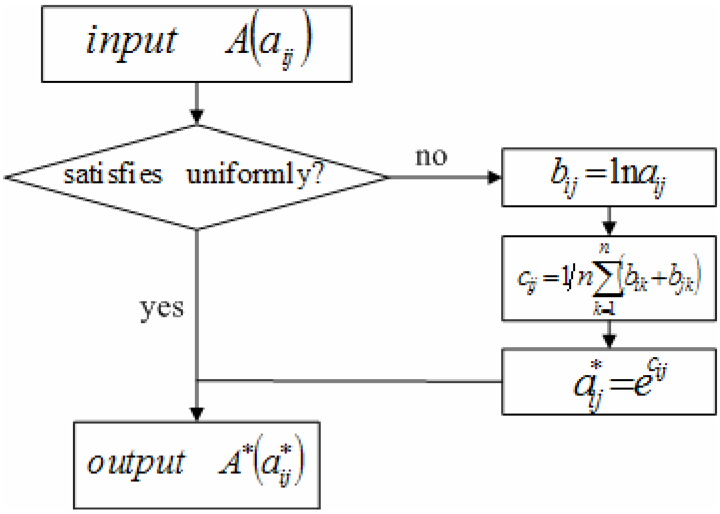

Figure 3. Correction Process of Judgment Matrix Satisfying Uniformly

The advantage of fuzzy comprehensive evaluation method is that it fully thinks of the complication of internal relatives of object and fuzziness of value system. But its disadvantage is that it mingles with much person subjectivity. This method has two main subjective factors specifically: ①to acquire weight doesn't associate with evaluation process; ②membership function is defined subjectively generally. In face of the disadvantage of single fuzzy comprehensive evaluation method, multi-layer fuzzy comprehensive evaluation adopts the following ways: index weight is calculated in AHP, membership function is established by using fuzzy self-evaluating model which uses evaluation object's sample data to determine membership function [7].The basic character of fuzzy self-evaluation model is: using evaluation objective sample data, not using Delphi to establish membership function. The following is simple introduce to the steps that the fuzzy self-judgment model defines membership function.

(1) Data standardized process

Presuming there are m schemes, expressed by subscript i, and n indexes, expressed by subscript j, then the $m\times n$ indexes values X_{ij} (i=1, 2, …, m, j=1, 2, …n) could be acquired by forecasting. X_{maxj} is the maximum value of the index j and X_{minj} is the minimum value of the index j in the m schemes, which is:

$$\begin{cases} X_{maxj} = max\{X_{1j}, X_{2j}, \ldots, X_{mj}\} \\ X_{minj} = min\{X_{1j}, X_{2j}, \ldots, X_{mj}\} \end{cases} \tag{1}$$

Defining the standardized data is:

$$\begin{cases} X_{ij}^{*} = \dfrac{X_{ij} - X_{minj}}{X_{maxj} - X_{minj}}, & (index \quad preferential \quad for \quad high \quad value) \\ X_{ij}^{*} = 1 - \dfrac{\left| X_{ij} - \overline{\overline{X}} \right|}{X_{maxj} - X_{minj}}, & (index \quad preferential \quad for \quad value \quad approximate \quad \overline{\overline{X}}) \\ X_{ij}^{*} = \dfrac{X_{maxj} - X_{ij}}{X_{maxj} - X_{minj}}, & (index \quad preferential \quad for \quad low \quad value) \end{cases} \tag{2}$$

After being processed above, the standardized data X_{ij}^{*} satisfies $0 \leqslant X_{ij}^{*} \leqslant 1$ and won't change the diversity of original data.

(2) Defining membership function

Table 2. Fuzzy Self-judgment Membership Function
(where：i=1,2,…m，j=1,2,…n）

	$X_{ij}^{*}\in[0,0.2]$	$X_{ij}^{*}\in[0.2,0.4]$	$X_{ij}^{*}\in[0.4,0.6]$	$X_{ij}^{*}\in[0.6,0.8]$	$X_{ij}^{*}\in[0.8,1.0]$
r_{j1}	1	$(0.4-X_{ij}^{*})/0.2$	0	0	0
r_{j2}	0	$1.0-r_{j1}$	$(0.6-X_{ij}^{*})/0.2$	0	0
r_{j3}	0	0	$1.0-r_{j2}$	$(0.8-X_{ij}^{*})/0.2$	0
r_{j4}	0	0	0	$1.0-r_{j3}$	$(1.0-X_{ij}^{*})/0.2$
r_{j5}	0	0	0	0	$1.0-r_{j4}$
Σ	1	1	1	1	1

The membership function defined with the method above all satisfy: $0\leqslant r_{jk}\leqslant 1$, $\sum_{k=1}^{5} r_{jk} = 1.0$.

Generally the standardized data X_{ij}^* are divided in [0,1] into 5 equal interval parts, which are [0，0.2]，[0.2，0.4]，[0.4，0.6]，[0.6，0.8]，[0.8，1.0]，corresponding to comment set {worst，worse，average，better，best}. In the divided interval, membership function is defined by using the form of linear clearance function, which is shown in Table 2. Fuzzy self-judgment model doesn't need determine membership degree matrix through Delphi, which reduces the subjectivity in defining the membership degree matrix. In addition, in order to suit to concrete problems better, the above-mentioned segment linear membership function could be corrected also.

4.2 The Calculation Process of Multi-layer Fuzzy Comprehensive Evaluation Method

In multi-layer fuzzy comprehensive evaluation method, "multi-layer" is that: which falls numerous factors into some layers that each layer includes less factors, then to do comprehensive evaluation each factor of the bottom layer; it gets the evaluation result layer by layer successively to the top layer. Let's take the indexes in Diagram 2 to illustrate the mode's computing steps [5] .

(1) Preparing work

① factor set

The indexes shown in figure 2 are seen as factor set and to divide them into three subsets according to different evaluation subject: U={U_1，U_2，U_3}={construction managers，users，the relevant ones}，where U_1={U_{11}，U_{12}}，U_2={U_{21}，U_{22}，U_{23}，U_{24}，U_{25}，U_{26} }，U_3={U_{31}，U_{32}，U_{33}，U_{34}，U_{35}，U_{36}，U_{37} }。

② judgment set

Presuming there are *m* comments, then judgment set V={V_1, V_2, …,V_m}. Corresponding to figure 2, take m=5，then judgment set V={V_1, V_2, V_3, V_4, V_5}={worst, worse, average, better, best }.

③ weight set

The first layer weight vector is A=（construction managers，users，the relevant ones）= (a_1，a_2，a_3)，the second layer weight vector is A_1=（facilities construction invest, public traffic travel proportion）= (a_{11}，a_{12})、A_2=（average social vehicle speed in arterial road, average public traffic speed in arterial road, average saturation degree in arterial road intersection, average social vehicle delay in arterial road intersection, average public traffic delay in arterial road intersection, average resident travel cost）= (a_{21}，a_{22}，a_{23}，a_{24}，a_{25}，a_{26})、A_3=（intersection air quality exceeding rate, segment air quality exceeding rate, road traffic's air pollution saturation degree, average traffic noise value in arterial road, average traffic noise value in intersection, fuel exhausting per passenger transportation volume, traffic space resources exhausting index）=(a_{31}，a_{32}，a_{33}，a_{34}，a_{35}，a_{36}，a_{37})。In fuzzy comprehensive judgment, weight's tiny change will bring great influence to judgment results, even though its process is very accurate. If the weights are defined unreasonable, it also leads to unreasonable scheme selection. Therefore, to define the weight plays an extremely important roll. In this article we take AHP to acquire each factor weight, so it only needs to set up judgment matrix and calculate priority vector.

④ Defining fuzzy operator

There are three types operators in fuzzy comprehensive judgment which are show in table 3. Operator ($\wedge,\vee$) judgment result is determined by the biggest value ,while the other values won't influence the result in a specific scope, which is suited to signal optimum situation; operator ($\wedge,\oplus$) is approximate to ($\wedge,\vee$) but more meticulous, so the judgment result they get reflects the membership indexes in certain degree ,which can be used in such situation that the operator ($\wedge,\vee$) is invalid; operator ($\bullet,\oplus$)balances all factors according to their weights, which embodies the total peculiarity and suits to such situation that requires total indexes. According to above analysis , this article adopt average-weighted operator ($\bullet,\oplus$)to evaluate BRT scheme.

Table 3. Three Types Popular Fuzzy Judgment Operator

operator	main factor determination type ($\wedge$, $\vee$)	main factor outstanding type ($\wedge$, $\oplus$)	average-weighted type ($\bullet$, $\oplus$)
$\vee^*$	$A\vee B=max\{A,B\}$	$A\oplus B=min\{A+B,1\}$	$A\oplus B=min\{A+B,1\}$
$\wedge^*$	$A\wedge B=min\{A,B\}$	$A\wedge B=min\{A,B\}$	$A\bullet B=A\times B$

(2) First-grade comprehensive judgment——fuzzy self-judgment model

Because the index values in each planning scheme all will be acquired by forecasting and all are quantitative ones, the task of evaluation is to sequence and select the optimum one for the alternative schemes on the base of these data. That is why this article won't adopt general fuzzy comprehensive judgment model but "fuzzy self-judgment model" to do first-grade judgment. When the membership degree matrix was born, it can do first-grade judgment. To evaluate each factor subset U_i and allocate weight A_i（lower layer-weight）which is defined by AHP, so the first-grade comprehensive judgment is:

$$B_i = A_i \cdot R_i = \{b_{i1}, b_{i2}, b_{i3}, b_{i4}, b_{i5}\} \qquad i = 1,2,3 \qquad (3)$$

The above formula indicates: the evaluation factors and evaluated objects' fuzzy relation A, through fuzzy translator R，forms fuzzy relation B between evaluated objects and evaluation grade.

(3) Second-grade comprehensive judgment

On the base of the first-grade, that it takes each subset U_i as a element and B_i as its signal factor judgment can make up judgment matrix, where

$$R = \begin{bmatrix} B_1 \\ B_2 \\ B_3 \end{bmatrix} = \begin{bmatrix} b_{11} & b_{12} & b_{13} & b_{14} & b_{15} \\ b_{21} & b_{22} & b_{23} & b_{24} & b_{25} \\ b_{31} & b_{32} & b_{33} & b_{34} & b_{35} \end{bmatrix} \qquad (4)$$

It is a signal factor judgment matrix of {U_1, U_2, U_3},so there is second-grade comprehensive judgment:

$$B = A \cdot R \tag{5}$$

(4) Comprehensive judgment value computation

comprehensive evaluation value $W = B \cdot C^T$, C^T is a transposed matrix of evaluation sets quantitative matrix. For example it can take C={1，2，3，4，5}，or other values, which is corresponding to the judgment set V={ worst, worse, average, better, best }, and the purpose is to differentiate each scheme's comprehensive evaluation value easily. The calculation steps of Multi-layer fuzzy comprehensive evaluation method are shown in figure 4 [5].

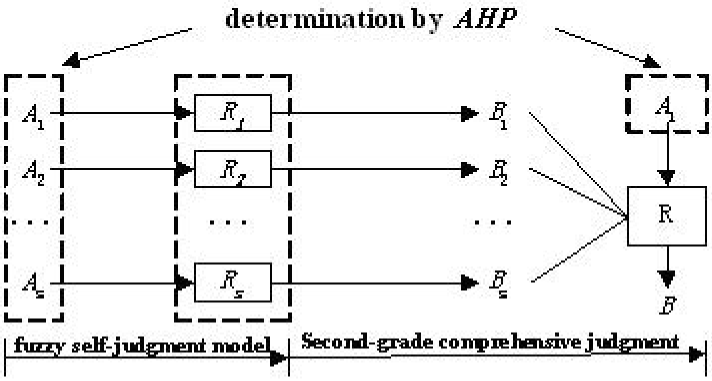

Figure 4. Multi-layer Comprehensive Fuzzy Evaluation Method Calculation Steps

5. EXAMPLE APPLICATION ANALYSIS

Let's quote data in《Comprehensive Transportation Planning of Bengbu City, China》（2002）[8] to do applied analysis of BRT scheme evaluation method. Where, scheme 1 is the current situation of Bengbu city's road traffic, scheme 2 and scheme 3 are the situation that has been planned by BRT projects:

- scheme 1（Current）：not implementing any BRT project；
- scheme 2（Planning）：planning to set two-way bus lane in two arterial roads Shengli Road and Chaoyang Road in Bengbu city（the other traffic management measures are the same as status quo）；
- scheme 3（Planning）：planning to set two-way bus lane in four arterial roads Shengli Road , Chaoyang Road, Jiefang road, Donghai road, etc（the four arterial roads are all two-way six-lane, and the road condition and traffic volume satisfy setting bus lanes）, and special entrance-lane for public traffic at intersection in part arterial roads（the other traffic management measures are the same as status quo）.

Respectively do traffic volume redistribution analogue to the above three schemes and the result are shown in Table 4. Scheme 1 indexes are acquired by survey, while the scheme 2 and scheme 3 indexes are acquired by forecasting with urban traffic management decision's supporting software "TranStar (Traffic Management Version)". Corresponding to Table 1 and Figure 2, it is put in order as Table 5, its evaluation subjects are reduced to two: construction managers and users.

Table 4. Current and Plan Scheme Index Value

index code (units)	scheme1	scheme2	scheme3
U_{11} (10000Yuan)	0	25	50
U_{12} (%)	23	24	25
U_{21} (km/h)	38.69	37.53	36.22
U_{22} (km/h)	21.54	26.43	29.68
U_{23}	0.79	0.78	0.77
U_{24} (s)	20.17	20.08	21.32
U_{25} (s)	24.55	24.75	18.74

Table 5 .Utilized Evaluation Index in Real

U_1	U_2
U_{11}	U_{21}
U_{12}	U_{22}
	U_{23}
	U_{24}
	U_{25}

(1) Data preparation

- factor set：$U=\{U_1, U_2\}$，$U_1=\{U_{11}, U_{12}\}$，$U_2=\{U_{21}, U_{22}, U_{23}, U_{24}, U_{25}\}$.
- judgment set：$V=\{V_1, V_2, V_3, V_4, V_5\}$={worst，worse，average，better，best}
- Defining weight vectors: The first layer weight A is assigned with the relative importance that the proportion of 1,3,5,7,9 and their reciprocals is to the construction managers and users. The judgment matrix standardized by U is shown in table 6. Calculating priority vectors with power root method can get A=（construction managers, users）=（ a_1, a_2）=（0.125, 0.875）. Since the judgment matrix is 2×2, it naturally satisfies the correspondence condition.

Table 6. Judgment Matrix Standardized by U

U	U_1	U_2
U_1	1	1/7
U_2	7	1

Table 7. Judgment Matrix Standardized by U_1

U_1	U_{11}	U_{12}
U_{11}	1	5
U_{12}	1/5	1

The judgment matrix standardized by U_1 is shown in table 7. Calculating second layer weight vectors with power root method can get A_1=（ a_{11}, a_{12}）=（0.833, 0.167）. Since the judgment matrix is 2×2, it naturally satisfies the correspondence condition. To define the second layer weight vector A_2 is much more complication. The judgment matrix standardized by U_2 is shown in table 8. The matrix is not able to satisfy the correspondence condition, therefore, it should be corrected with the method shown in figure 3. The judgment matrix shown in Table 9 is the right matrix that has been corrected and satisfies the correspondence condition, then A_2=（ a_{21}，a_{22}，a_{23}，a_{24}，a_{25}）=（0.194，0.301，0.059，0.175，0.271）。

Table 8. Judgment Matrix Standardized by U_2

U_2	U_{21}	U_{22}	U_{23}	U_{24}	U_{25}
U_{21}	1	1/3	5	3	1/3
U_{22}	3	1	5	1/3	3
U_{23}	1/5	1/5	1	1/3	1/3
U_{24}	1/3	3	3	1	1/3
U_{25}	3	1/3	3	3	1

Table 9. Corrected Judgment Matrix Standardized by U_2

U_2	U_{21}	U_{22}	U_{23}	U_{24}	U_{25}
U_{21}	1.000	0.644	3.273	1.108	0.714
U_{22}	1.552	1.000	5.079	1.719	1.108
U_{23}	0.306	0.197	1.000	0.338	0.218
U_{24}	0.903	0.582	2.955	1.000	0.644
U_{25}	1.401	0.903	4.585	1.552	1.000

- data standardization: The result of data standardization by formula 2 is shown in table 10.

Table 10. Data Standardization Result

index code	scheme 1	scheme 2	scheme 3
U_{11}	1	0.5	0
U_{12}	0	0.5	1
U_{21}	1	0.53	0
U_{22}	0	0.601	1
U_{23}	0	0.5	1
U_{24}	0.927	1	0
U_{25}	0.033	0	1

(2) First-grade judgment

According to the data in table 10, construct a membership matrix R_{ij} in the method shown in table 2 and make first-grade judgment (fuzzy self-judgment), the operator should adopt average-weighted operator (• , ⊕). $B_{ij} = A_i \cdot R_{ij}$, the subscript i =1,2 respectively refer to construction managers and users, and the subscript j =1,2,3 respectively refer to scheme 1, scheme 2, scheme 3.

Scheme 1:

$$B_{11} = A_1 R_{11} = \begin{pmatrix} 0.833 & 0.167 \end{pmatrix} \cdot \begin{bmatrix} 0 & 0 & 0 & 0 & 1 \\ 1 & 0 & 0 & 0 & 0 \end{bmatrix} = \begin{pmatrix} 0.167 & 0 & 0 & 0 & 0.833 \end{pmatrix}$$

$$B_{21} = A_2 R_{21} = \begin{pmatrix} 0.194 & 0.301 & 0.059 & 0.175 & 0.271 \end{pmatrix} \cdot \begin{bmatrix} 0 & 0 & 0 & 0 & 1 \\ 1 & 0 & 0 & 0 & 0 \\ 1 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0.365 & 0.635 \\ 1 & 0 & 0 & 0 & 0 \end{bmatrix} = \begin{pmatrix} 0.631 & 0 & 0 & 0.064 & 0.305 \end{pmatrix}$$

Scheme 2:

$$B_{12} = A_1 R_{12} = \begin{pmatrix} 0.833 & 0.167 \end{pmatrix} \cdot \begin{bmatrix} 0 & 0.5 & 0.5 & 0 & 0 \\ 0 & 0.5 & 0.5 & 0 & 0 \end{bmatrix} = \begin{pmatrix} 0 & 0.5 & 0.5 & 0 & 0 \end{pmatrix}$$

$$B_{22} = A_2 R_{22} = \begin{pmatrix} 0.194 & 0.301 & 0.059 & 0.175 & 0.271 \end{pmatrix} \cdot \begin{bmatrix} 0 & 0.35 & 0.65 & 0 & 0 \\ 0 & 0.775 & 0.225 & 0 & 0 \\ 0 & 0 & 0.995 & 0.005 & 0 \\ 0 & 0 & 0 & 0 & 1 \\ 1 & 0 & 0 & 0 & 0 \end{bmatrix} = \begin{pmatrix} 0.271 & 0.301 & 0.252 & 0.001 & 0.175 \end{pmatrix}$$

Scheme 3：

$$B_{13} = A_1 R_{13} = \begin{pmatrix} 0.833 & 0.167 \end{pmatrix} \cdot \begin{bmatrix} 1 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 1 \end{bmatrix} = \begin{pmatrix} 0.833 & 0 & 0 & 0 & 0.167 \end{pmatrix}$$

$$B_{23} = A_2 R_{23} = \begin{pmatrix} 0.194 & 0.301 & 0.059 & 0.175 & 0.271 \end{pmatrix} \cdot \begin{bmatrix} 1 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 1 \\ 0 & 0 & 0 & 0 & 1 \\ 1 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 1 \end{bmatrix} = \begin{pmatrix} 0.369 & 0 & 0 & 0 & 0.631 \end{pmatrix}$$

(3) Second-grade judgment

$R_i = \begin{vmatrix} B_{1i} \\ B_{2i} \end{vmatrix}$, i=1,2,3 refer to scheme 1, scheme 2 and scheme 3, then second-grade fussy comprehensive judgment $B_i = A \cdot R_i$.

Scheme 1:

$$B_1 = A \cdot R_1 = \begin{pmatrix} 0.125 & 0.875 \end{pmatrix} \cdot \begin{bmatrix} 0.167 & 0 & 0 & 0 & 0.833 \\ 0.631 & 0 & 0 & 0.064 & 0.305 \end{bmatrix} = \begin{pmatrix} 0.573 & 0 & 0 & 0.056 & 0.371 \end{pmatrix}$$

Scheme 2:

$$B_2 = A \cdot R_2 = \begin{pmatrix} 0.125 & 0.875 \end{pmatrix} \cdot \begin{bmatrix} 0 & 0.5 & 0.5 & 0 & 0 \\ 0.271 & 0.301 & 0.252 & 0.001 & 0.175 \end{bmatrix} = \begin{pmatrix} 0.237 & 0.326 & 0.283 & 0.001 & 0.153 \end{pmatrix}$$

Scheme 3:

$$B_3 = A \cdot R_3 = \begin{pmatrix} 0.125 & 0.875 \end{pmatrix} \cdot \begin{bmatrix} 0.833 & 0 & 0 & 0 & 0.167 \\ 0.369 & 0 & 0 & 0 & 0.631 \end{bmatrix} = \begin{pmatrix} 0.427 & 0 & 0 & 0 & 0.573 \end{pmatrix}$$

(4) Comprehensive judgment results

Through above calculation, the advantage and disadvantage of schemes could be compared. For example, the membership degree of scheme 3 to "best" is 0.573, which is bigger than 0.371 of scheme 1 and 0.153 of scheme 2. However, in order to make the sequencing of the scheme much more intuitional, the vectors are usually transferred into a comprehensive judgment value: $W_i = B_i \cdot C^T$, i=1, 2, 3 refers to scheme 1, scheme 2 and scheme 3. The calculation"." refers to multiplication in common sense.

Scheme 1: $W_1 = B_1 \cdot C^T = (0.573 \quad 0 \quad 0 \quad 0.056 \quad 0.371) \cdot (1 \quad 2 \quad 3 \quad 4 \quad 5)^T = 2.652$

Scheme 1: $W_2 = B_2 \cdot C^T = (0.237 \quad 0.326 \quad 0.283 \quad 0.001 \quad 0.153) \cdot (1 \quad 2 \quad 3 \quad 4 \quad 5)^T = 2.52$

Scheme 1: $W_3 = B_3 \cdot C^T = (0.427 \quad 0 \quad 0 \quad 0 \quad 0.573) \cdot (1 \quad 2 \quad 3 \quad 4 \quad 5)^T = 3.292$

According to the operation result a conclusion could be made: the third scheme is the best one, the second scheme is a little worse than the first. The reason is that the second scheme doesn't design bus priority in intersection, while its bus lanes are shorter than the third scheme, so it can't bring scope benefit. So the key to implement BRT is bus priority in intersection, while there must be enough link length to implement BRT.

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